

# WorldView-3 Geometric Calibration

**Chris Comp and David Mulawa, DigitalGlobe**



# WorldView-3 Satellite Overview

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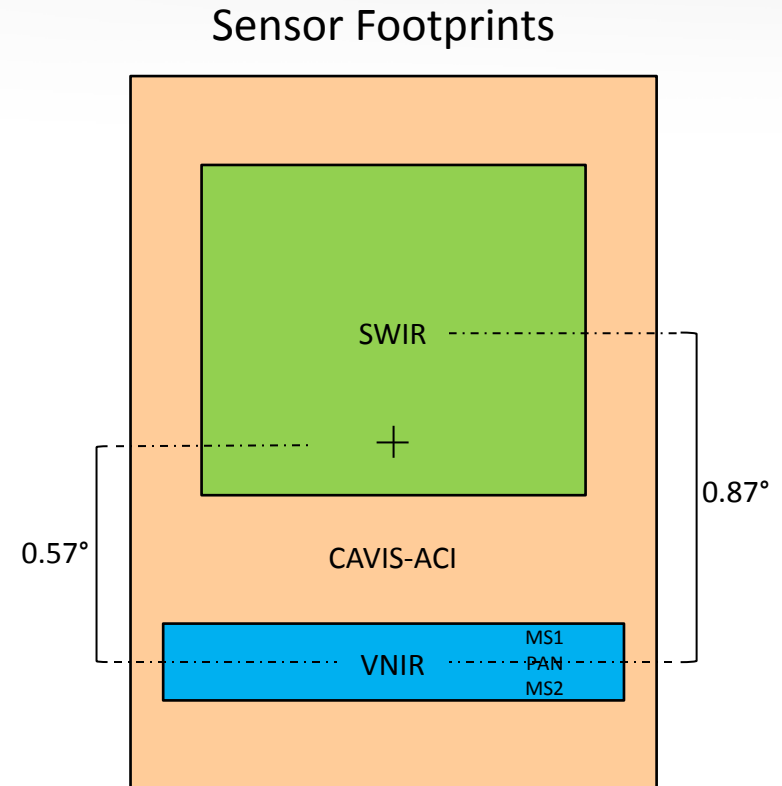
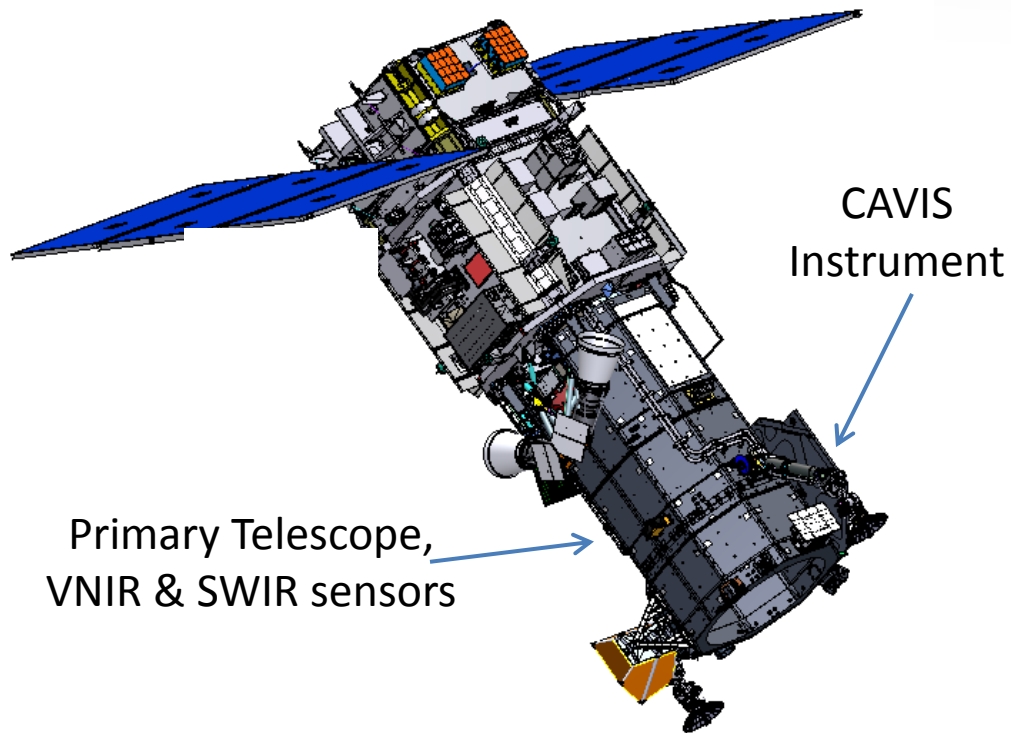
- Launched August 13, 2014
  - Vandenberg AFB
  - 617 km sun-synchronous orbit
  - Local time descending node 10:30am
- Vital Statistics
  - 2800 kg mass
  - 5.7 m tall x 2.5 m across (7.1 m across including solar arrays)
  - CMG momentum actuators
  - General Dynamics Viceroy GPS Rx (single frequency)
  - Ball CT-602 star trackers
  - Northrop Grumman SSIRU gyro
- Calibration timeline
  - Satellite checkout and commissioning completed L+5 days
  - First images collected L+6 days
  - Primary/VNIR instrument geometric and radiometric calibration completed L+45 days

# WorldView-3 Has Three Imaging Instruments

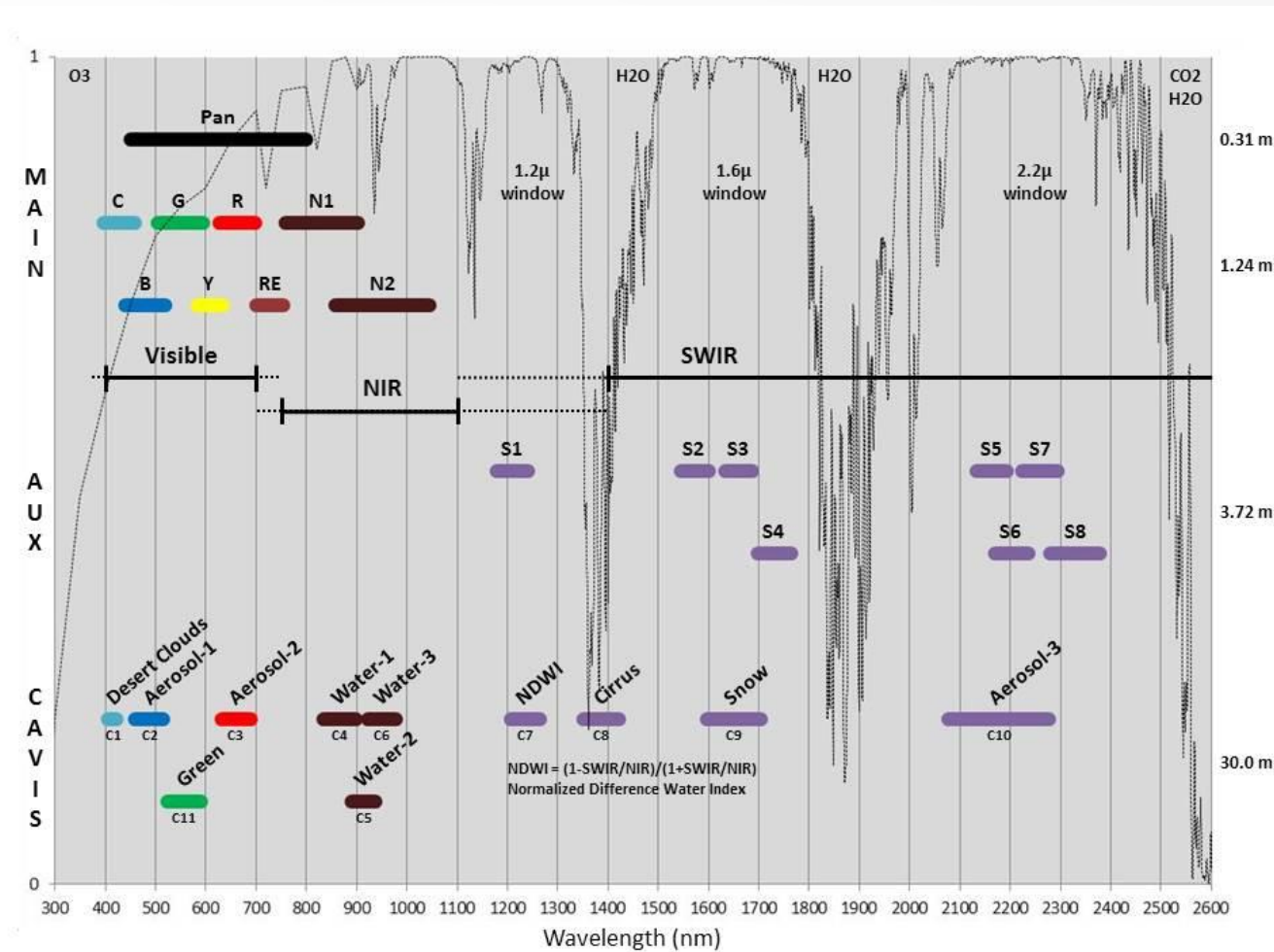
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- VNIR Primary Instrument
  - Visual and Near Infrared
  - Panchromatic band, 0.31 m GSD
  - 8 Multispectral bands, 1.24 m GSD
    - Red, Green, Blue, Red Edge, Yellow, Coastal, NIR1, NIR2
  - Comprises primary telescope and focal-plane unit
- SWIR Instrument
  - 8 Short-wave Infrared bands, 3.7 m native GSD and 7.5 m resampled GSD
  - Also uses primary telescope and separate auxiliary focal-plane unit
- CAVIS Instrument
  - Cloud, Aerosol, Water-Vapor, Ice, Snow, Atmospheric Calibration Instrument (CAVIS-ACI, or simply CAVIS)
  - 12 bands, 30 m GSD
    - 7 VNIR bands
    - 5 SWIR bands
  - Standalone optics and focal-plane package

# WorldView-3 Satellite Overview



# WorldView-3 Spectral Bands



# Geometric Calibration

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- VNIR geometric calibration completed
  - Covered in following slides
- SWIR
  - Internal geometric calibration completed
  - SWIR-to-VNIR alignment still in progress
- CAVIS initial geometric calibration completed
- Full SWIR and CAVIS calibration results at JACIE 2016 Workshop
  - Not presented here due to time constraints

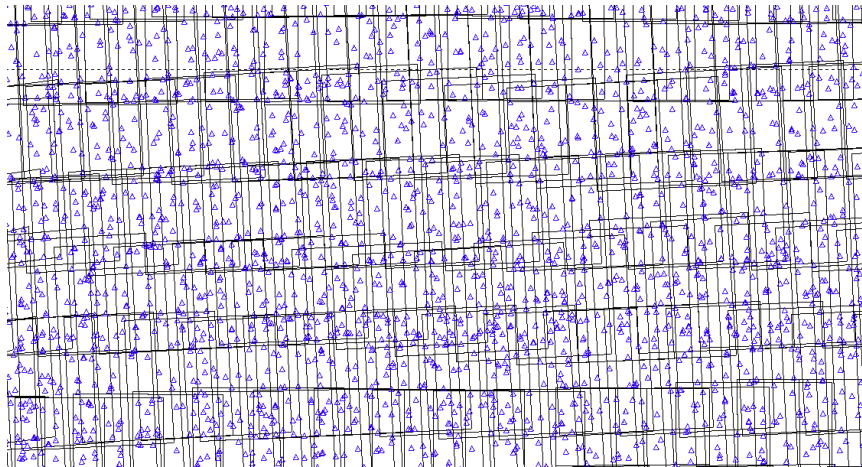
# Field Angle Map (FAM) Calibration Methodology

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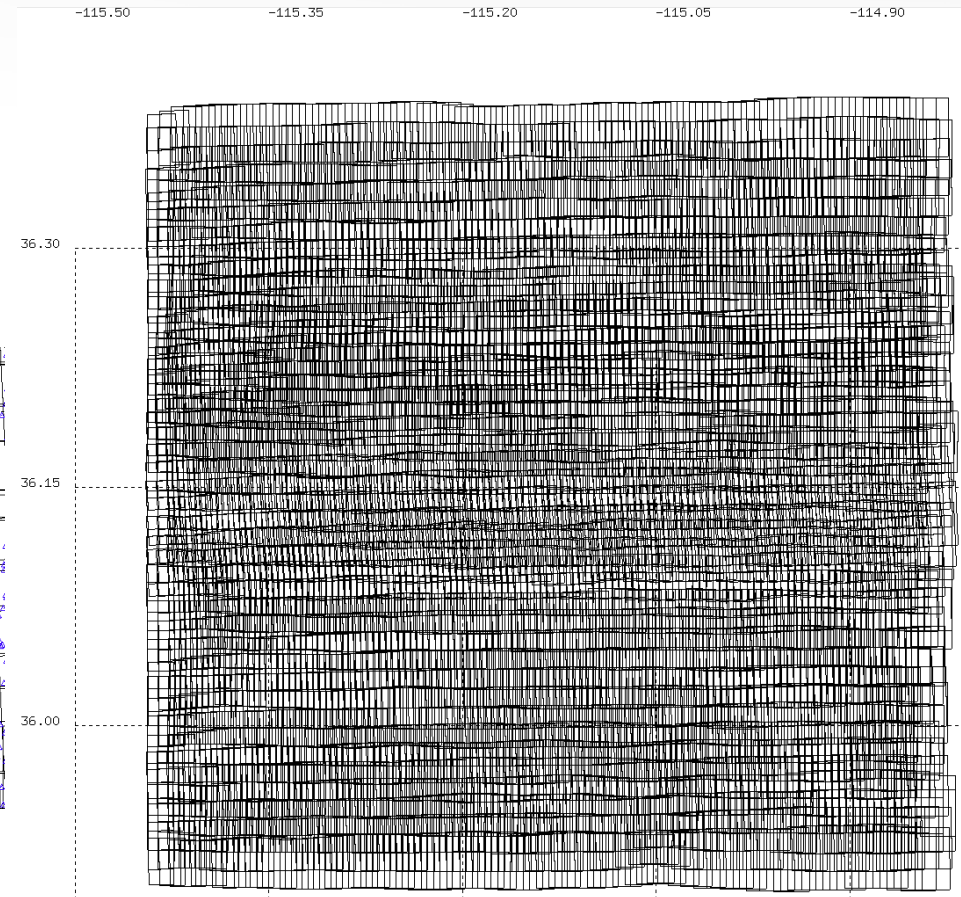
- Calibration Control
  - Digital aerial images collected with a strong geometry.
  - Controlled with a dense pattern of GPS surveyed photo identifiable control points.
  - Developed with a very dense set of object space tie points to be used as satellite calibration control points.
- Collection of satellite calibration imagery
  - Collection of multiple passes over several days to cover the extent of the operational FOV of the satellite.
- Calibration data measurement
  - Automated image correlation between the aerial control imagery and the satellite calibration imagery.
    - This leads to a massive number of photo rays, all of which have GCP values.
- Calibration analysis
  - Optical distortion parameters are estimated in a Self Calibration Block Adjustment with Added Parameters.
  - A posteriori analysis of image residuals can be used to adjust detector positions on the focal plane.
- Calibration verification
  - Additional satellite imagery is collected and measured as above. Image residual analysis is performed.
  - Calibration parameters are used in image reconstruction and standard image products are made and tested.
  - Band to band registration is measured.
  - Visual inspection is used to look for subarray shears.
  - Second generation products such as Digital Elevation Models are made and analyzed.

# Las Vegas Geometric Test Range

- Digital Aerial reference imagery from DMC camera
- 50km by 50km extent
- Ground Sample Distance of 30 cm



Detail showing object point density

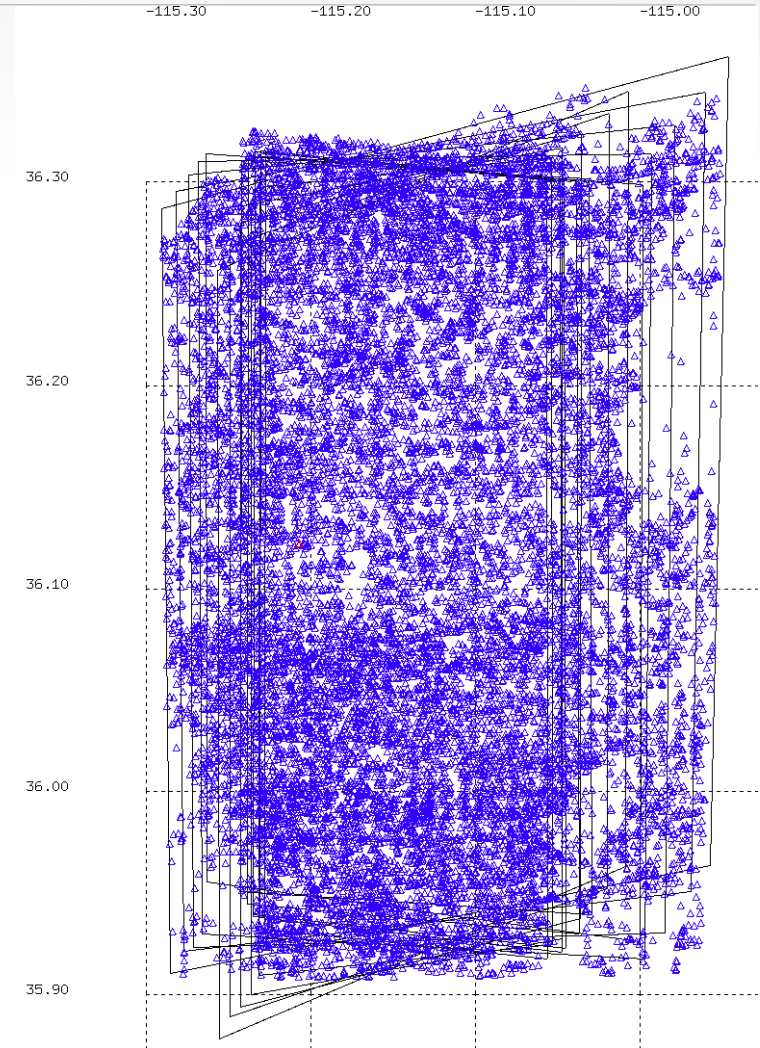


Footprint plot of the Las Vegas Range

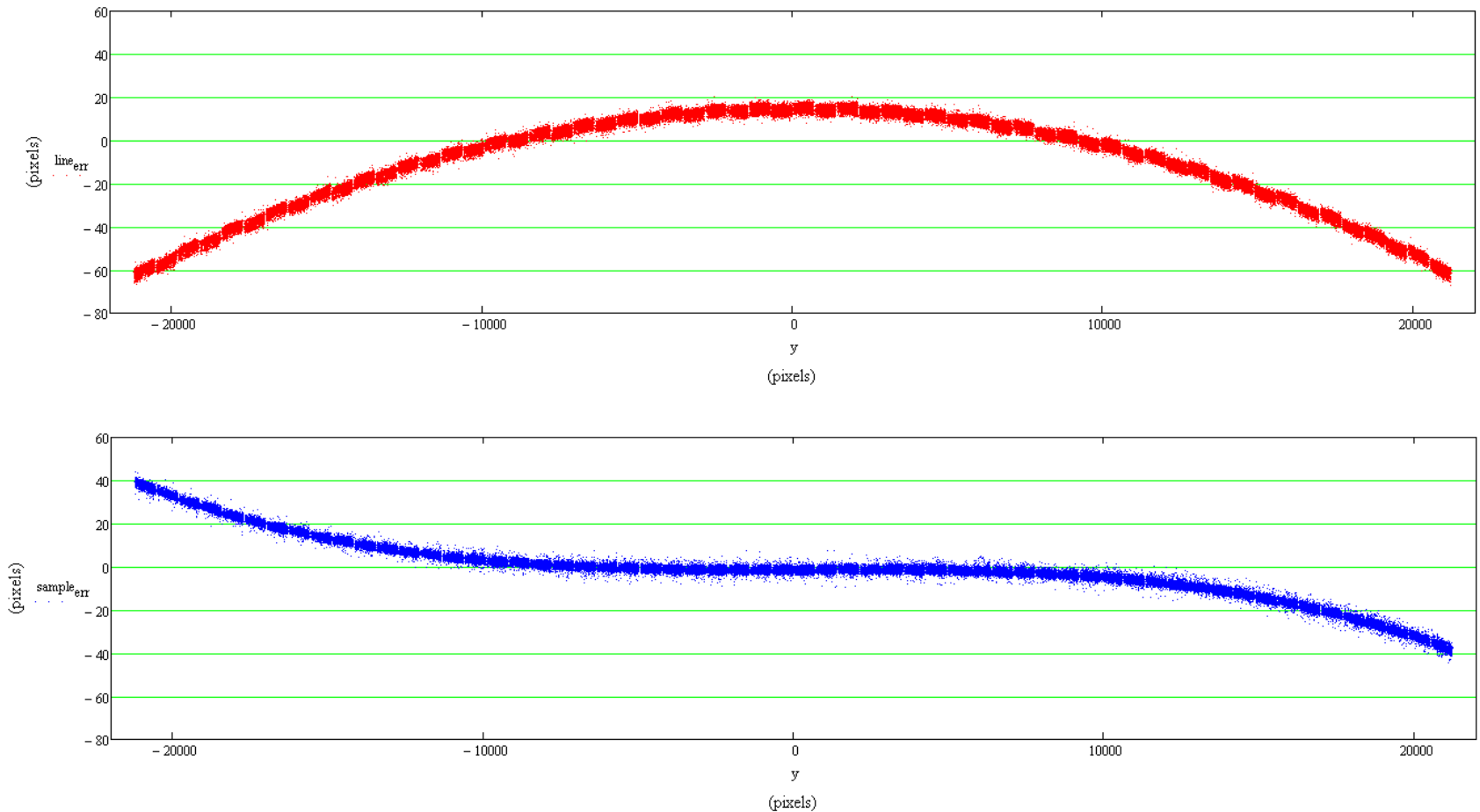


# Image Strip Coverage Over Geometric Calibration Test Ranges

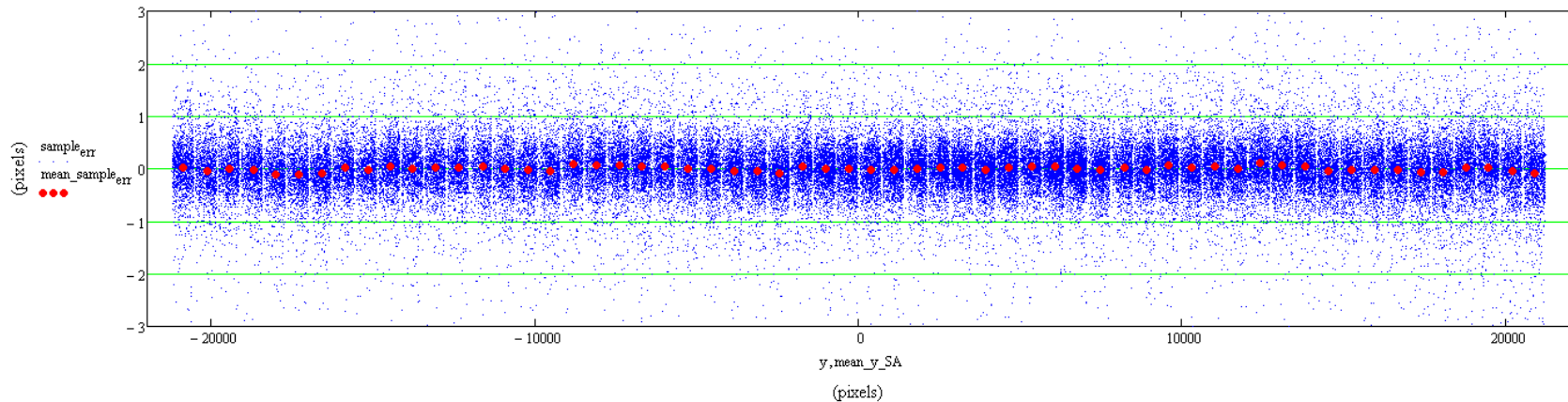
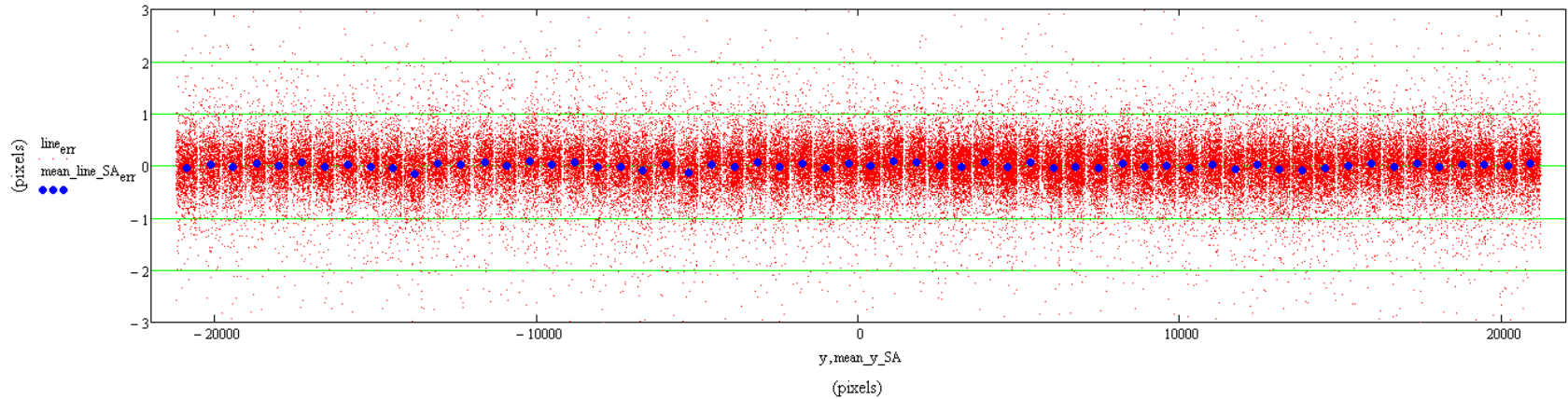
- WV3 Imagery for calibration
  - 15 strips collected on 2014 Aug 25 and 26 over Las Vegas Test Range
  - footprints and GCP pattern shown on right
- WV3 Imagery for verification of calibration
  - 66 Pan and 55 MS strips over Las Vegas and Phoenix Test Ranges



# Pan Band FAM Errors Pre-Calibration



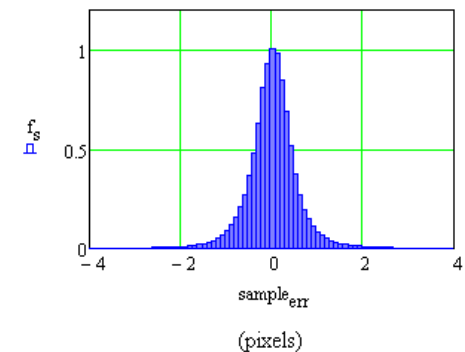
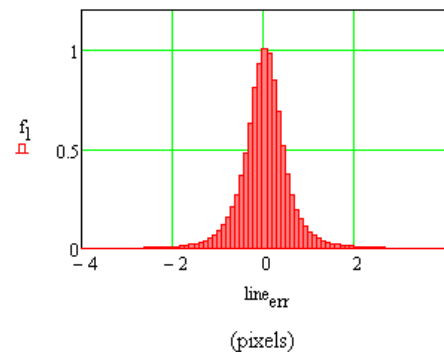
# Pan Band FAM Errors Post-Calibration (Detail)



# FAM Calibration Verification Results

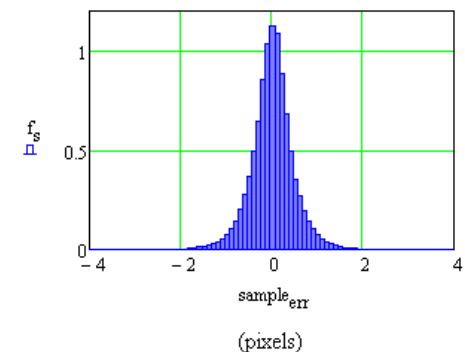
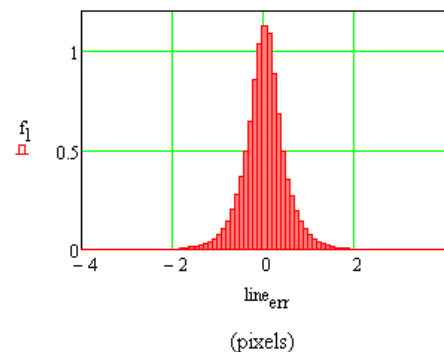
- Panchromatic

- Strips = 66
- Image measurements = 361,101
- Standard deviation
  - Line = 0.60 pixels
  - Sample = 0.62 pixels



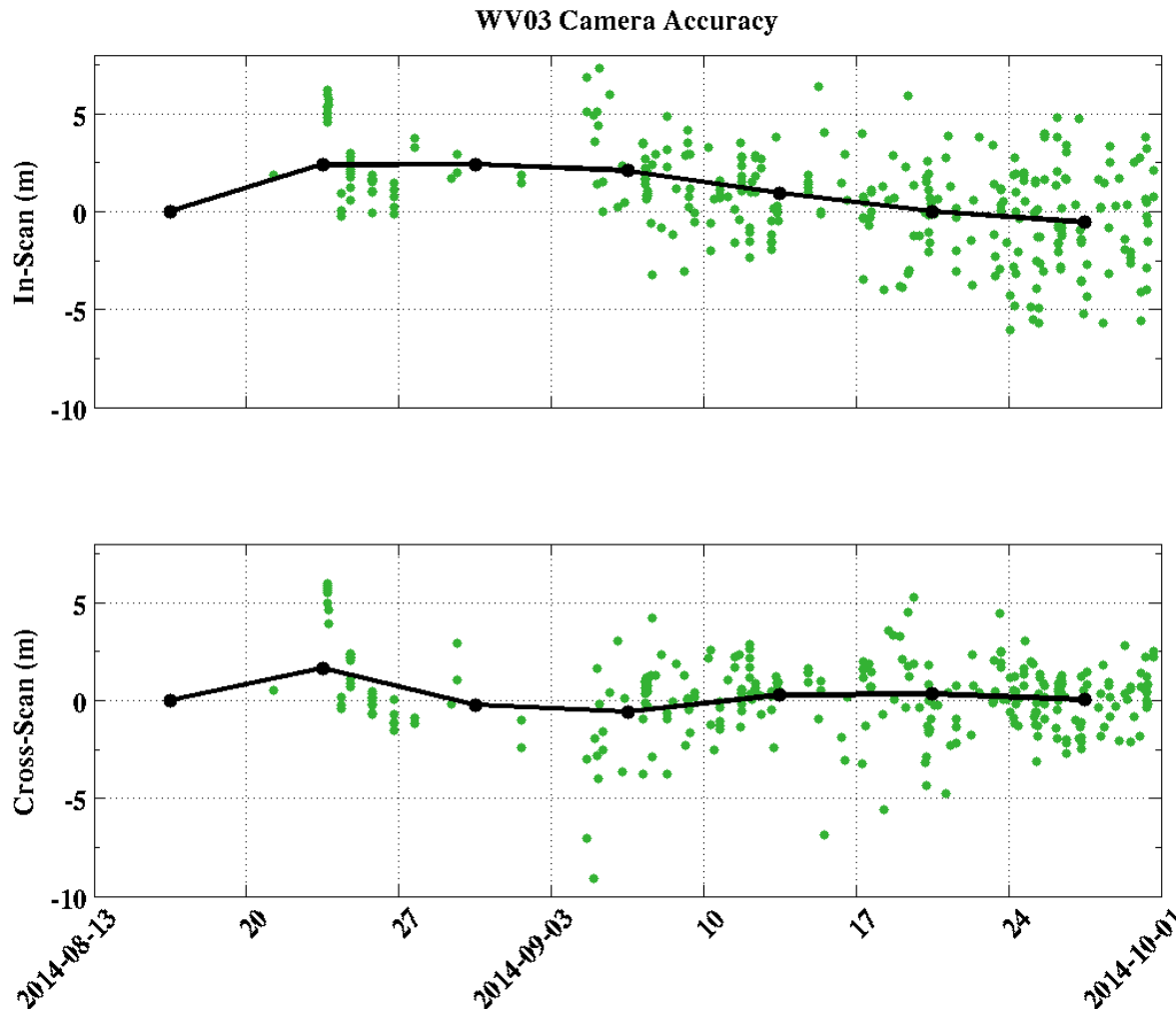
- Multispectral

- Strips = 55
- Image measurements = 1,134,467
- Standard deviation
  - Line = 0.48 pixels
  - Sample = 0.42 pixels





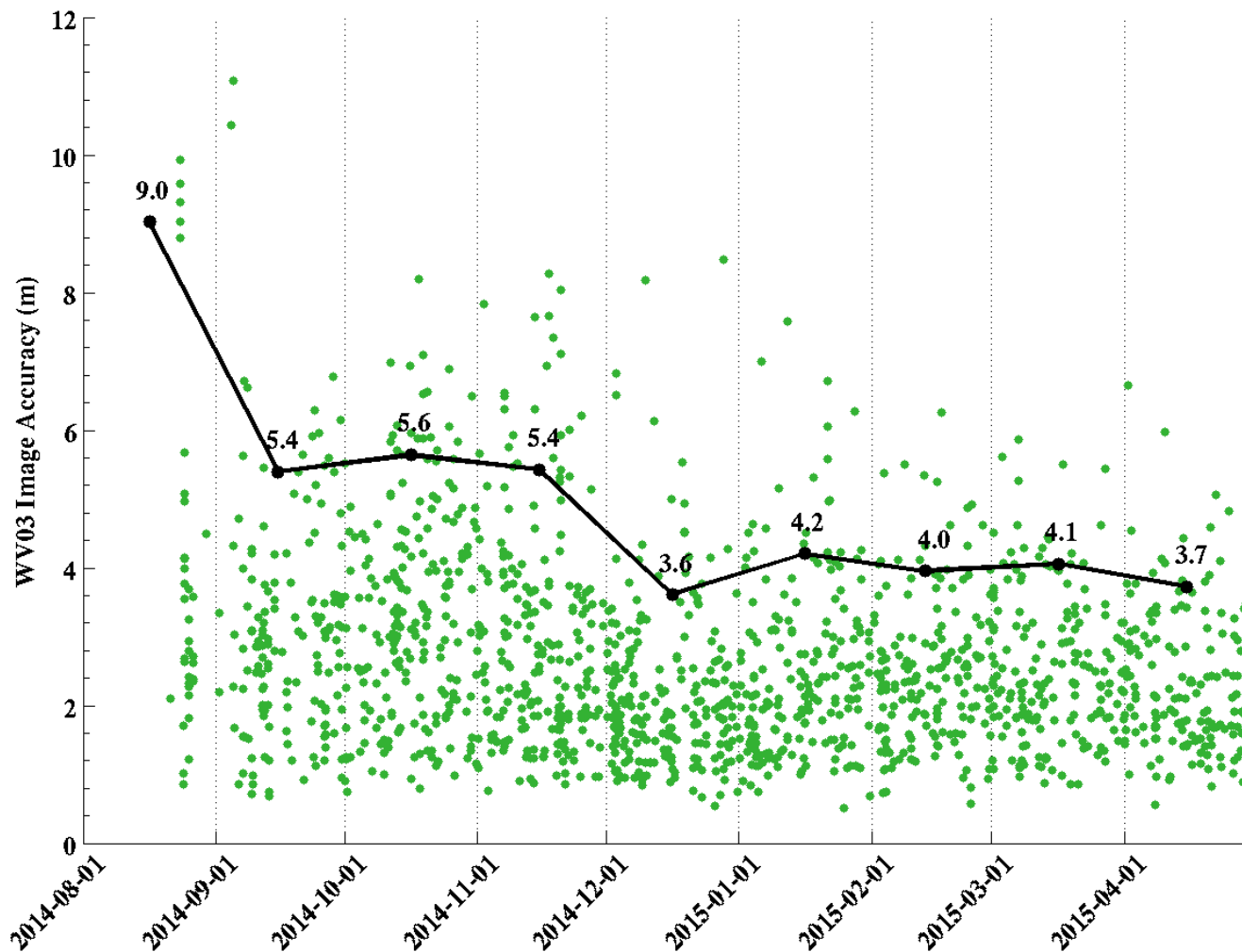
# WorldView-3 Horizontal Accuracy: First 6 weeks



Launch: Aug 13  
Fully Calibrated: Oct 1

Each dot is the mean  
in-scan or cross-scan  
accuracy of a  
calibration image  
measured in the  
camera frame

# WorldView-3 Horizontal Accuracy: First 9 Months



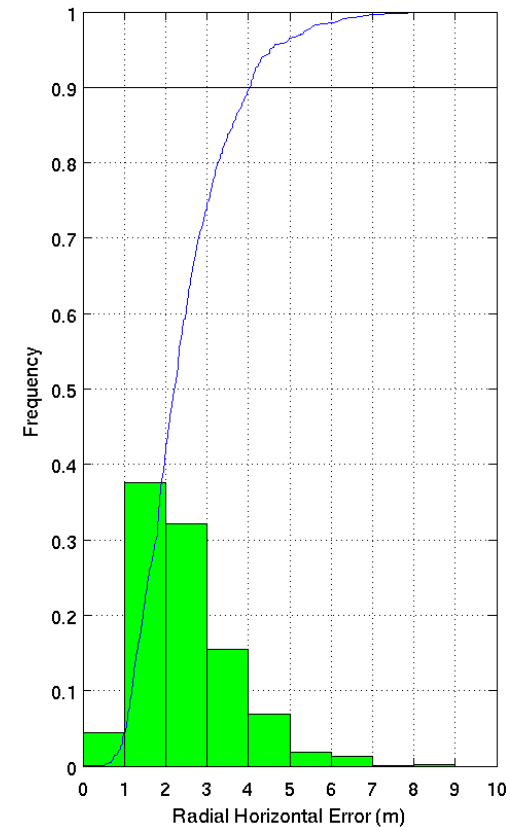
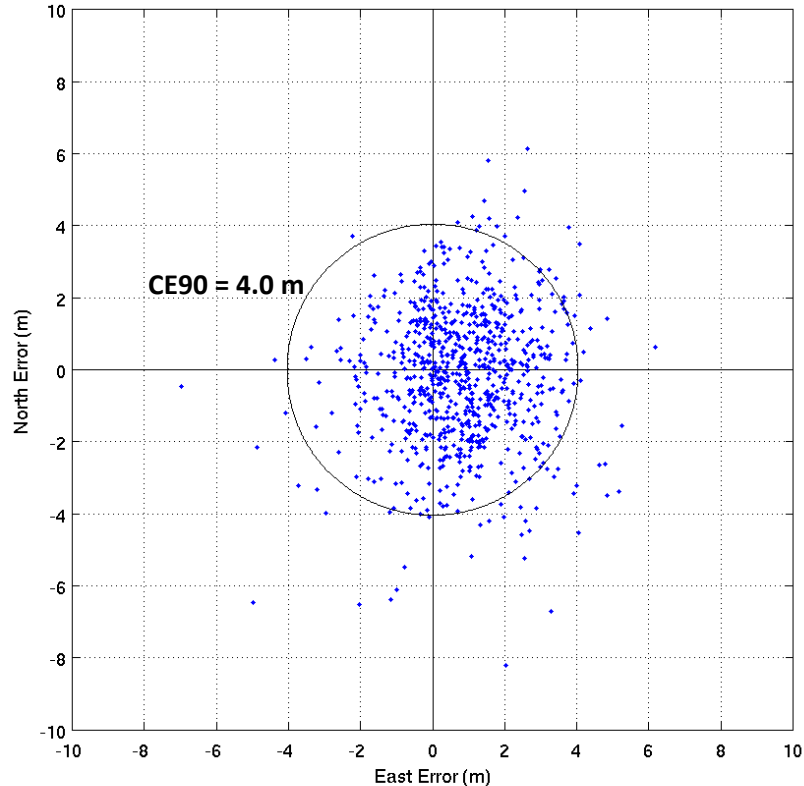
Each green dot is the mean radial accuracy of a calibration image measured in the geodetic frame.

Each black dot is the CE90 accuracy for the month shown.


# WorldView-3 Horizontal Accuracy: Statistics




N = 801 images [*\*after 11/21/14\**]  
 Avg(East) = 0.8 m    Avg(North) = -0.1 m


CE90 = 4.0 m  
 RMSE = 2.7 m



# WorldView-3 Vertical Accuracy: Industry Partner




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## PhotoSat verifies accuracy of DigitalGlobe's 30 cm WorldView-3 satellite elevation data to within 15 cm


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LIDAR Elevation Grid PhotoSat's WorldView-3 Elevation Grid

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### Engineers to benefit from high quality elevation products

VANCOUVER, March 25, 2015 /PRNewswire/ - PhotoSat is pleased to announce that the elevation data processed from DigitalGlobe's new 30 centimeter resolution satellite, WorldView-3, has been verified as accurate to within 15 centimeters. DigitalGlobe is a leading global provider of commercial high-resolution earth imagery products and services, and is the first company to offer 30 cm resolution satellite imagery commercially.

(Photo: <http://photos.prnewswire.com/prnh/20150325/194293>)

For the study, PhotoSat produced a 50 cm grid of elevations using its proprietary geophysical processing technology with stereo satellite images taken by WorldView-3. The resulting elevations were then compared to a 50 cm LIDAR elevation grid in Southeast California, accurate to approximately 5 cm in elevation and available on the [OpenTopography](#) website. The size of the comparison area was 88 square kilometers. The resulting 15 cm RMSE elevation accuracy was impressively achieved using a single ground reference point. The full WorldView-3 accuracy study is available on the PhotoSat website at [www.photosat.ca/pdf/garlock-30cm-wv3-elevation-accuracy-report-mar2015.pdf](http://www.photosat.ca/pdf/garlock-30cm-wv3-elevation-accuracy-report-mar2015.pdf).



# 2014 DigitalGlobe Systems Geolocation Accuracy

System	Mono			Stereo				
	<i># images</i>	<i>CE90 (m)</i>	<i>RMSE radial (m)</i>	<i># pairs</i>	<i>CE90 (m)</i>	<i>RMSE radial (m)</i>	<i>LE90 (m)</i>	<i>RMSE H (m)</i>
Ikonos	2	8.2	8.2	-	-	-	-	
QuickBird-2	320	16.8	10.8	-	-	-	-	-
WorldView-1	1254	4.8	3.1	208	3.7	2.4	2.9	1.8
GeoEye-1	57	4.0	2.7	113	4.1	2.7	4.0	2.4
WorldView-2	915	5.5	3.5	185	3.7	2.6	3.7	2.2
WorldView-3*	801	4.0	2.7	83	3.1	2.2	2.6	1.6

- Based on rigorous (physical) model; no adjustment of imagery
- Collection geometry <35 degrees off nadir angle, stereo convergence angle 45 degrees
- \*WorldView-3 includes 2015 data to achieve significant data set

# Bidding Farewell to Commercial Imagery Pioneers

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- Ikonos
  - World's first sub-meter commercial Earth-imaging satellite
  - Launched September 24, 1999
  - 15 years of service
  - 599,744 images collected
  - 408 million sq. km.
  - Retired March 31, 2015
- QuickBird-2
  - Launched October 18, 2001
  - 13 years of service
  - 529,942 images collected
  - 636 million sq. km.
  - Deorbited January 27, 2015

# Thanks to the DigitalGlobe Cal-Val Team

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- Geometric Calibration
  - Brendan Clarke
  - David Mulawa
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  - Woodson Bercaw
  - Chris Comp
- Radiometric Calibration
  - Nancy Podger
  - Todd Updike
  - Michele Kuester